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NASA Workshop on Future Directions in Surface Modeling and Grid Generation

W. R. Van Dalsem, R. E. Smith, Y. K. Choo,
L. D. Birckelbaw, and A. A. Vogel

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NASA Workshop on Future Directions in Surface Modeling and Grid Generation

W. R. Van Dalsem, Ames Research Center, Moffett Field, California
R. E. Smith, Langley Research Center, Hampton, Virginia
Y. K. Choo, Lewis Research Center, Cleveland, Ohio
L. D. Birckelbaw and A. A. Vogel, Ames Research Center, Moffett Field, California

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Space Administration

Ames Research Center
Moffett Field, California 94035-1000

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PREFACE

The NASA workshop was initiated by the Office of Aeronautics and Exploration Technology (OAET). The purpose was to assess U.S. capabilities in surface modeling and grid generation and take steps to improve the focus and pace of these disciplines within NASA. The organization of the workshop centered around overviews from NASA centers and expert presentations from U.S. corporations and universities. Small discussion groups were held and summarized by group leaders. Brief overviews and a panel discussion by representatives from the DoD were held, and a NASA only session concluded the meeting. The program for the workshop is attached. Also, attached is a list of workshop attendees.

To encourage candor, no written papers were required, and the public availability of vugraphs was left to the speaker's discretion. No vugraphs from individual presentations are included herein. Each session of the workshop was summarized by the session chairman, and an edited compilation of the summaries is presented herein.

In the NASA Program Planning Session summary there are five recommended steps for NASA to take to improve the development and application of surface modeling and grid generation.

NASA Workshop on Future Directions in Surface Modeling and Grid Generation

December 5-7, 1989

NASA Ames Research Center, NAS Auditorium (Bldg. 258, Rm. 127)

Tuesday, December 5

8:00	Registration (NAS Lobby)	
8:30	Welcome	Kristin Hessenius, NASA
8:45	Report on 1989 AGARD Meeting	Joseph Steger, U.C. Davis

SESSION 1 **NASA Overviews**
William Van Dalsem, Chair

9:15	Ames Research Center	Alison Vogel
9:45	Langley Research Center	Robert Smith
10:15	*BREAK*	
10:30	Lewis Research Center	Yung Choo
11:00	Johnson Space Center	C. P. Li
11:30	Marshall Space Flight Center	Paul K. McConnaughey
12:00	*LUNCH*	

SESSION 2 **Aerospace Industry Overviews**
Aaron Snyder, Chair

1:00	McDonnell Aircraft	Ray Cosner
1:25	Pratt & Whitney	David Ives
1:50	General Dynamics	John Steinbrenner
2:15	*BREAK*	
2:30	Boeing Commercial Airplane	Bernard Su
2:55	General Electric	Ian Jennions
3:20	Calspan	Jack Benek
3:45	Grumman	Giuseppe Volpe
4:10	*BREAK*	

SESSION 3 **DOD Overviews and Panel Discussion**
Larry Birckelbaw, Chair and Panel Moderator

4:25 -- 5:25		
	Eglin Air Force Base	Dave Belk
	Wright Aeronautical Laboratory	Don Kinsey
	NSRDC (David Taylor)	Rod Coleman
	Ballistics Research Laboratory	Charles Nietubicz
5:30 -- 6:30	*SOFTWARE DEMONSTRATIONS* *NAS Graphics Laboratory (Room 125)*	

Wednesday, December 6

8:00	Registration (NAS Lobby)	

SESSION 4 **University Overviews**
Robert Smith, Chair

8:30	Block-Structured Grid Generation	Joe Thompson, Mississippi State
8:55	Unstructured Grid Generation	Timothy Baker, Princeton
9:20	Surface Modeling	Robert Barnhill, Arizona State
9:45	Surface Grid Generation	Ki D. Lee, University of Illinois
10:10	*BREAK*	

SESSION 5 **Emerging Technology Briefings**
Francis Enomoto, Chair

10:30	CAD Software Trends	Mark Sheppard, RPI
10:45	Computer Hardware Trends	Thomas Lasinski, NASA Ames
11:00	Standards	Velvin Watson, NASA Ames
11:15	Grid Quality Issues	Peter Eiseman, Columbia
11:30	*LUNCH*	
12:45	Hyperbolic Surface Grid Generation	Joseph Steger, U.C. Davis
1:00	Hybrid AI/Procedural Systems	John F. Dannenhoffer III, UTRC
1:15	Interactive Grid Generation	Jeffery Cordova, Visual Computing

SESSION 6 **Group Discussions and Panel Discussion**
Yung Choo, Chair

1:30 -- 3:30 Small Group Discussions (Bldg. 258, Rms. 111, 128, 221, & Bldg. T045, Rm. 115)

Group	Moderator
Surface Modeling and Surface Grid Generation	Pam Richardson
Field Grid Generation	Reese Sorenson
Emerging Technology (Software)	Dennis Huff
Emerging Technology (Hardware)	Bill Van Dalsem

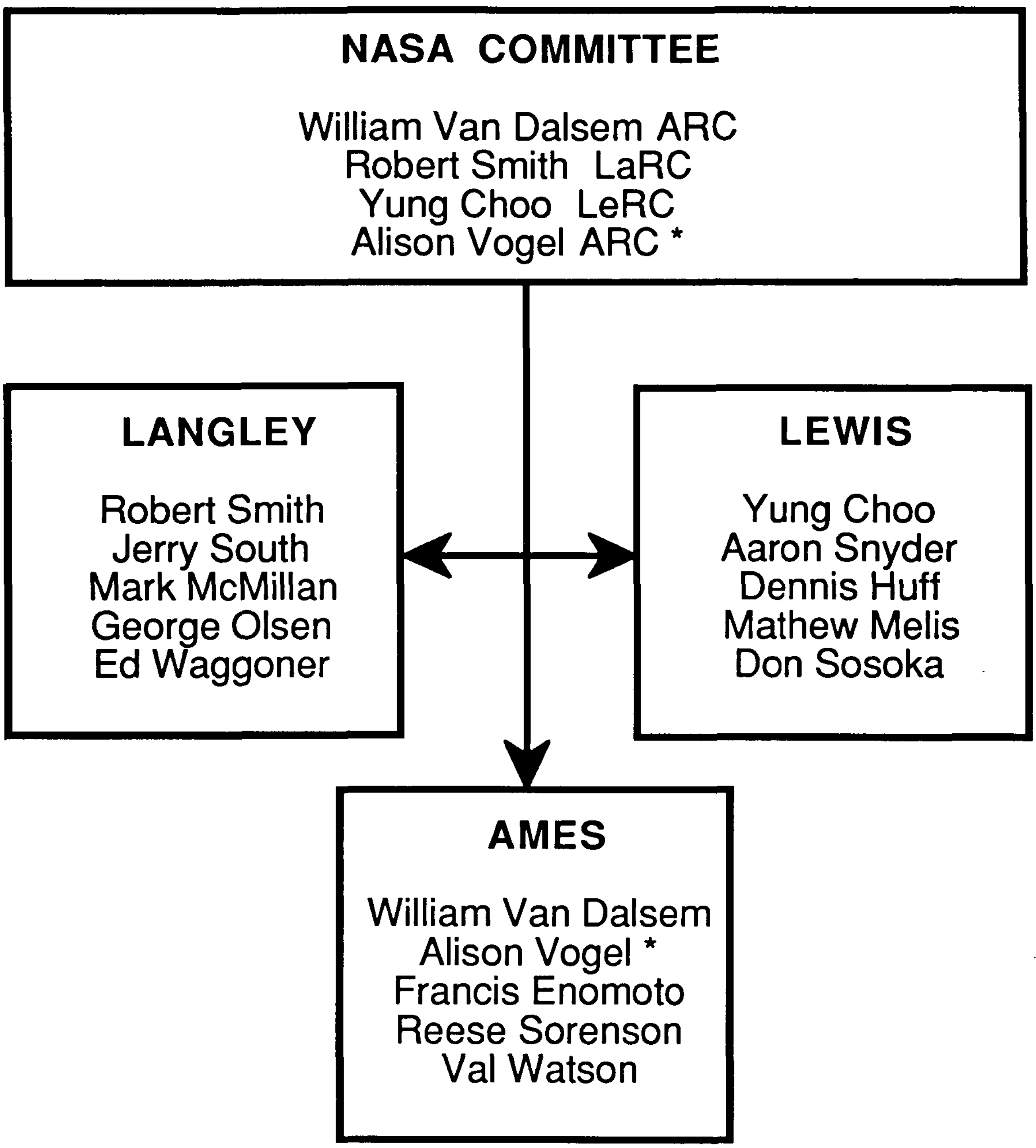
3:30 -- 5:00 Group Reports and Panel Discussion
Jerry South, Moderator

5:00 -- 7:00 *SOCIAL HOUR*
NAS Lobby

Thursday, December 7

8:30 -- 12:00	NASA Program Planning Session	***NASA ONLY***
12:00	Adjourn	

NASA OAST
1989 GRID GENERATION
WORKSHOP COMMITTEE



* 3/90 replaced by Larry Birckelbaw

NASA OVERVIEWS

Overviews were presented by representatives from the Ames, Langley, and Lewis Research Centers and the Johnson and Marshall Space Centers. The NASA research and space centers have come to rely heavily on CFD to accomplish agency missions. Despite the broad range of applications among the centers, their is a universal requirement for sophisticated and rapid surface-modeling and grid-generation tools. Each center has addressed this requirement independently, and in all cases, significant resources have been allocated to the problem.

Among the research centers, the approach appears to be that individual organizations (sometimes division level, most often branch level) have dedicated just enough resources to satisfy their local needs. In the area of surface modeling, CAD/CAM packages originally chosen to satisfy engineering requirements (constructing wind tunnel models, etc.), have been pressed into service to supply CFD surface grids. For grid generation, specialized software for specific projects has been developed in-house or acquired from outside sources. Very few concerted efforts towards developing general purpose surface-modeling and grid-generation software are apparent. However, three notable efforts are the GRAPE code at Ames, the TURBO code at Lewis and the SMART code at Langley. Overall, there has resulted a proliferation of surface-modeling and grid-generation software packages. At the space centers, the requirement for rapid response to proposed design changes has generated more focused activities. At the space centers, much as in industry, there is a heavy reliance on acquired software.

At present, virtually all "project-oriented" CFD within NASA utilizes patched or overset structured-grid schemes. Unstructured schemes are under intensive study and produce impressive results, but appear to require additional advances before wide-spread application. Across the research centers, in addition to unstructured grid generation, there are research activities on adaptive techniques, expert systems, grid quality, and domain decomposition.

AEROSPACE INDUSTRY OVERVIEWS

Industry overviews were presented by representatives from McDonnell Douglas, Pratt & Whitney, General Dynamics, Boeing, General Electric, Calspan, and Grumman. The industry representatives indicate that their companies rely heavily on CFD for the design of advanced aircraft and propulsion systems. They feel that they are constrained by the quality of grids and the cost of creating them. They indicated that geometry modeling from blue prints (CAD data) and domain decomposition have been inefficient and labor intensive.

Interactive processes applied on advanced workstations have improved the situation. One notable example of this is the interactive menu-driven computer software system called GRIDGEN. With this software, which was developed by General Dynamics Corporation under contract to the Air Force, surface grid generation and domain decomposition has become a much quicker and easier visual process.

The industry representatives gave the impression that their grid generation efforts are well organized and highly focused to support company products. Although the industries have been using their resources for more near-term goals, they also expressed their interest in long-term technologies in unstructured grids, grid adaptation, grid quality and expert systems.

DoD OVERVIEWS AND PANEL DISCUSSION

The DoD panel consisted of representatives from the Air Force (2), Army (1) and Navy (1). Each representative presented a short overview of their organizations' surface-modeling and grid-generation activity. In most respects, the DoD organizations have similar requirements as the NASA-OAET centers. They have a combination of ongoing research and projects.

In the 1980s, the DoD has sponsored major developments of grid-generation systems. The two most notable activities have been the GRIDGEN software mentioned in the industry overview and sponsored by the Air Force Wright Research and Development Center, and the EAGLE software developed by Mississippi State University and primarily sponsored by the Air Force Armament Laboratory, Eglin Air Force Base.

The Wright Research and Development Laboratory has assumed a government leadership role in the production of public-domain geometry modeling and grid generation software. Not only are they responsible for the GRIDGEN development, they are responsible for VIRGO, PLUTO, and I3G software. They publish a newsletter called *The Meshenger* to inform interested organizations on current grid generation activity. Also, they are now involved in a major procurement with Computation Mechanics Corporation for unstructured grid generation software.

The panel discussion, which followed the overviews, centered around the issues of future funding and the possibility of merging some of the more mature systems such as the EAGLE and GRIDGEN codes. There was a good deal of uncertainty about the future funding levels with the unstructured grid contract from Wright Research and Development Center being the only new contract activity.

UNIVERSITY OVERVIEWS

Four university representatives presented overviews. They were from Arizona State University, the University of Illinois, Mississippi State University, and Princeton University. Their respective topics of discussion were surface modeling, surface grid generation, block-structured grid generation and unstructured grid generation.

Universities have been instrumental in the development of surface modeling technology starting with project MAC at MIT in the early 1960s, and grid generation technology starting at Mississippi State University in the early 1970s.

Surface modeling and surface grid generation continue to be the most time-consuming and tedious aspect of the overall grid-generation problem. Even though surface modeling has reached a high level of sophistication, it has been directed primarily at visualization and manufacturing rather than analysis such as CFD. It is now an objective to direct the attention of Computer-Aided-Geometry-Design (CAGD) expertise in the university community towards CFD requirements. Surface-surface intersection, topology and surface smoothing are being investigated for the purpose of creating CFD grids.

Blocked-structured grid generation, with continuity across block boundaries or overlapping, is highly developed. Algebraic and differential techniques, developed largely in the university environment, are efficiently applied to compute grid points in the interior of blocks. The difficulties with blocked-structured grids are the logistics of domain decomposition and the transfer of information between partially overlapping blocks. Often, intelligent decisions (artificial or human) are required to achieve acceptable results.

Currently, for unstructured grid generation, there are two competing techniques: (1) Delaunay triangulation; and (2) advancing front. The primary advantage of these techniques, compared with blocked-structured grid generation, is that regions can be decomposed into tetrahedral cells without defining complex intermediate block-boundaries. Both unstructured techniques, although well-developed, are computationally time-consuming compared to structured techniques. At the time of the workshop, there was no generalized unstructured grid-generation software, such as GRIDGEN or EAGLE, publicly available. However, it is likely that such software will be forthcoming in the near future. The most important aspect of unstructured grids, relative to CFD, is the development of efficient robust and accurate solution techniques for the governing equations of motion.

Universities continue to be committed to the development of grid-generation technology. Topics such as software user-friendliness, data management, surface smoothness, grid quality, visualization, and artificial intelligence are being investigated for surface modeling and grid generation. At Mississippi State University the Center for Computational Field Simulation has been established. This center, under the sponsorship of the National Science Foundation, has as one of its primary purposes the advancement of surface modeling and grid generation. The center is proposing a national coalition for the development of a comprehensive surface-modeling and grid-generation code.

EMERGING TECHNOLOGY BRIEFINGS

The purpose of this session was to take a glimpse at new technical developments affecting surface modeling and grid generation. Specific topics centered around computer architecture and performance, automated grid generation, grid quality, man-machine interaction/visualization and standardization. The speakers were from NASA, industry and academia. Perhaps the most profound effect on surface modeling and grid generation is computer performance and architecture. Surface modeling, domain decomposition and grid generation are inherently interactive processes. During the 1980s, scientific workstations with graphics firmware emerged, and since their introduction, there has been significant improvements in performance. It is anticipated that in the next five years, high performance workstations will have the computational power of current low-end supercomputers. The impact of this increased performance will not only allow more complex and refined geometries to be analyzed, but will also provide a capability to perform additional and new functions simultaneously with surface modeling and grid generation. These functions include grid-quality analysis, expert advising, and solution visualization. The trend in computer architecture is toward parallel processing, and this implies that techniques and algorithms must be developed for this environment.

Transfer of geometry, grids and CFD data between individuals and organizations requires that standard formats be established. Also, software standards are necessary to execute the same codes on a variety of equipment. The standards that relate to geometry, computer graphics and grids are IGES, LaWGS and PDES/STEP. The graphics standards are GKS and PHIGS. The DoD is mandating the use of IGES (and PDES in the future) through its Computer Aided Acquisition and Logistics (CAAL) initiative. Non-uniform Rational B-splines (NURBS) are expected to become a standard for surface representation. The PLOT3D format has become a defacto standard for CFD data, and the FAST interface software potentially could become a standard interface within NASA for high performance workstations.

In the application of expert or knowledge-based systems, some progress has been made with 2D problems. However, expert systems are likely to play a more important role in the 1990s. Expert systems are good for data-driven and goal-driven tasks. Specialized software must be applied to the data to invoke rules for a given analysis. Most CFD and grid generation have been driven by algorithms in procedural systems. A hybrid system, which would use an expert system to control a set of procedures that share a data pool, would combine the efficiency of procedural systems with the flexibility of expert systems. It is hypothesized that such a system is ideally suited for grid adaptation, domain decomposition, solution interpretation, and design iteration.

Grid quality measures, such as orthogonality and smoothness are inherent in a grid generation technique. When these variables have poor quality, they can adversely affect a solution of the flow equations. Also, the ability of a grid generation technique to concentrate grid points, where there are high gradients in the solution domain, directly affects solution accuracy. Most often, grid quality is visually evaluated, similar to solution evaluation, using workstation technology. The use of expert systems to aid in the evaluation is emerging.

Grid adaptation, which is closely associated with grid quality, conforms a grid to meet the accuracy requirement of a given solution. Considerable research has been performed in this area, but automated grid adaptation is not extensively used today for most CFD calculations. This is because of the additional computational overhead and the difficulty in maintaining good grid quality during the adaptation process. However, it is anticipated that emerging computer hardware and algorithm technology will eventually allow virtually all flow solutions to have adaptive grids.

High performance workstations have revolutionized surface modeling and grid generation through visualization and interactive responses. The use of two-dimensional images to visualize three-dimensional domains is at a very high level of development. The use of holography, to create three-dimensional rendering of objects, and lasers, to rapidly construct plastic models, are emerging technologies that will likely enhance to the ability to evaluate grids and flow field solutions.

GROUP DISCUSSIONS AND PANEL DISCUSSION

Group discussions on Surface-Modeling and Surface-Grid Generation, Field-Grid Generation, Emerging Technology (Software) and Emerging Technology (Hardware) were held. In addition to a broad-based discussion, each group was asked to express what they thought should be NASA's role relative to the group subject. After the group discussions, the group leaders formed a panel to present what occurred in the individual meetings. The main issues and roles are:

Issues

Surface modeling is highly developed but needs to be focused for CFD application.

General surface-modeling and grid-generation software (not research codes) are required to support CFD analysis about complex configurations.

The skills for advanced CFD applications must include surface modeling and grid generation. (A critical mass must be achieved.)

Research is still required in grid adaptation, grid quality unstructured algorithms, domain decomposition, expert systems, and parallel processing.

NASA's Roles

Continue to perform research on new grid-generation technology.

Establish standard formats for grids and CFD solutions.

Establish central libraries of software, grids and CFD solutions.

Support the coordination of surface modeling, grid generation and CFD within the U.S. government and industry.

Develop, within the agency, a first-rate surface-modeling and grid-generation capability to support advanced CFD applications.

NASA PROGRAM PLANNING SESSION

This session focused on what NASA can and should do to improve its surface-modeling and grid-generation capabilities. First, NASA is in a good position to establish standards and maintain libraries of grid and CFD data. The NAS facility and organization can be brought to bear on this item. The personnel at the research and space centers involved with geometry and CFD have been largely identified and provide a basis for coordination between centers. The agency management should be made aware that a critical mass of skills must be devoted to geometry technology to support CFD applications. NASA must identify CAD and grid-generation software to be used for advanced CFD applications.

CONCLUSIONS AND RECOMMENDATIONS

It was re-affirmed at the workshop that geometry modeling and grid generation are critical in computational aerospace design. It was evident that significant progress in grid generation methods and tools has been made over the last decade. Also, surface modeling through CAD is quite advanced but not well coordinated with grid generation for CFD. Faster and better surface-modeling and grid-generation tools are still needed as we challenge more complicated geometries and pursue more accurate numerical predictions.

Problems that were identified at the workshop can be summed up as follows:

> Few organizations have large, well-equipped, multi-disciplinary efforts required to produce useful surface-modeling and grid-generation tools. Because the development teams must include specialist from several discipline areas, obtaining the proper skill mix and coordination are not easy.
>
> Activities in the U.S. lack coordination and cooperation.

Basic technologies that require further development include:

- Geometry acquisition and modeling techniques
- Effective user interfaces
- Solution-adaptive grid generation techniques
- Automatic domain decomposition
- Grid generation algorithms
- Grid generation expert systems
- Grid quality analysis

In addition, the geometry-modeling and grid-generation techniques need to be extended across disciplines (aerodynamics, structures, heat transfer).

Based on the workshop findings and the organization committee's subsequent discussions, the following recommendations are being made to NASA-OAET and local management:

1. Establish a Surface-Modeling and Grid-Generation Focal Group at each NASA Research Center that performs a significant amount of Computational Fluid Dynamics. The focal group would coordinate the surface modeling and grid generation activity at the center and be sufficiently manned to serve as a critical mass for new developments and applications.

2. Establish a NASA Surface-Modeling and Grid-Generation Steering Committee to coordinate NASA's geometry-modeling and grid-generation activities and to oversee and advocate these activities. This committee should be led by NASA headquarters.

3. Improve coordination of U.S. activities through the development and implementation of:
   - An aerospace geometry exchange standard,
   - Geometry-data and grid-generation software libraries.

   Charge the Numerical Aerodynamics Simulation (NAS) organization with the responsibility of implementing and maintaining geometry-data and software libraries.

4. Implement future NASA software for surface modeling and grid generation using the FAST interactive graphics environment. Make the FAST library available to U.S. industry/university community for new structured-grid implementations. Also, begin development of FAST enhancements required for a complete grid-generation user environment, including (for example) a data base system for unstructured grids. Finally, begin design and implementation of a next-generation user/developer grid generation environment utilizing recent advances in software technology.

5. Define the requirements for NASA geometry-modeling software. This should be the first task for the NASA steering committee. Evaluate candidate existing public domain and commercial packages.

CONFERENCE ATTENDEES

Lt. David J. Amdahl
WARCMM
Wright-Patterson AFB, OH 45133

Mr. Chris Atwood
NASA Ames Research Center
MS T045-2
Moffett Field, CA 94035

Dr. Timothy Baker
Research Scientist
MAE Department
Engineering Quadrangle
Princeton University
Princeton, NJ 08544

Dr. Robert Barnhill
Department of Computer Science
Arizona State University
Tempe, AZ

Mr. Tim Barth
NASA Ames Research Center
MS 202A-14
Moffett Field, CA 94035

Mr. Tim Beach
NASA Lewis Research Center
MS SVR-1
21000 Brookpark Road
Cleveland, OH 44135-3191

Dr. David M. Belk
AFATL/FXA
Eglin Air Force Base, Fl 32542

Dr. Jack Benek
Head, CFD Section
MS 600
CALSPAN/AEDC OPERATIONS
Arnold Air Force Base, TN 37389

Mr. Brad Bennett
NASA Ames Research Center
MS 258-1
Moffett Field, CA 94035

Ms. Kim Bey
NASA Langley Research Center
MS 395
Hampton, VA 23665-5225

Mr. Bob Biedron
NASA Langley Research Center
MS 128
Hampton, VA 23665-5225

Mr. Larry Birckelbaw
NASA Ames Research Center
MS T045-2
Moffett Field, CA 94035

Dr. Bruce Blaylock
NASA Ames Research Center
MS 258-5
Moffett Field, CA 94035

Mr. Mike Bockelie
NASA Langley Research Center
MS 125
Hampton, VA 23665-5225

Dr. Denny Chaussee
NASA Ames Research Center
MS 258-1
Moffett Field, CA 94035

Dr. Kalpana Chawla
NASA Ames Research Center
MS T045-2
Moffett Field, CA 94035

Mr. Simon Chen
NASA Lewis Research Center
MS SVR-1
21000 Brookpark Road
Cleveland, OH 44135-3191

Dr. Roderick V. Chima
NASA Lewis Research Center
MS 5-11
21000 Brookpark Road
Cleveland, OH 44135-3191

Dr. Yung K. Choo
NASA Lewis Research Center
MS 5-11
21000 Brookpark Road
Cleveland, OH 44135-3191

Dr. Gil Chyu
NASA Ames Research Center
MS 227-6
Moffett Field, CA 94035

Dr. Roderick M. Coleman
David Taylor Naval Research Center
Code 1501
Bethesda, MD 20084

Dr. Jeffery Cordova
Visual Computing
883 N. Shoreline Blvd. B210
Mountain View, CA 94043

Mr. Gary Cosentino
NASA Ames Research Center
MS 227-6
Moffett Field, CA 94035

Dr. Ray Cosner
McDonnell Aircraft Company
Mail Code 0341260
P. O. Box 516
St. Louis, MO 63116-0516

Dr. Russell Cummings
NASA Ames Research Center
MS 258-1
Moffett Field, CA 94035

Dr. John F. Dannenhoffer III
Computational Fluid Dynamics
Research
United Technologies Research Center
East Hartford, CT 06108

Ms. Carol Davies
NASA Ames Research Center
MS 230-3
Moffett Field, CA 94035

Dr. Peter Eiseman
Program Development Corp. of
Scarsdale, Inc.
300 Hamilton Ave. Suite 409
White Plains, NY 10601

Mr. Francis Enomoto
NASA Ames Research Center
MS 227-2
Moffett Field, CA 94035

Mr. Jim Fenbert
NASA Langley Research Center
MS 412
Hampton, VA 23665-5225

Dr. Raymond E. Gaugler
NASA Lewis Research Center
MS 412
21000 Brookpark Road
Cleveland, OH 44135-3191

Mr. Ray Gomez
NASA Johnson Space Center
Mail Code ED311
Houston, TX 77058-3696

Ms. Aga Goodsell
NASA Ames Research Center
MS 227-2
Moffett Field, CA 94035

Mr. Clyde Gumbert
NASA Langley Research Center
MS 159
Hampton, VA 23665-5225

Dr. Terry Holst
NASA Ames Research Center
MS 258-1
Moffett Field, CA 94035

Mr. Dennis L. Huff
NASA Lewis Research Center
MS 77-6
21000 Brookpark Road
Cleveland, OH 44135-3191

Dr. Danny P. Hwang
NASA Lewis Research Center
MS 86-7
21000 Brookpark Road
Cleveland, OH 44135-3191

Dr. David Ives
Pratt &Whitney
Mail Stop 161-16
East Hartford, CT 06108

Dr. Ian Jennions
General Electric Company
MDA - 323
1 Neumann Way
Cincinnati, Ohio 45215

Mr. Paul Keller
NASA Ames Research Center
MS 227-2
Moffett Field, CA 94035

Dr. Don Kinsey
WARCMM
Wright-Patterson AFB, OH 45133

Dr. Goetz Klopfer
NASA Ames Research Center
MS 258-1
Moffett Field, CA 94035

Dr. Stephen Klotz
NASA Ames Research Center
MS T045-2
Moffett Field, CA 94035

Mr. Ronald Langhi
NASA Ames Research Center
MS 227-6
Moffett Field, CA 94035

Dr. Thomas Lasinski
NASA Ames Research Center
MS T045-2
Moffett Field, CA 94035

Dr. K. D. Lee
Univ. of Illinois at Urbana-Champaign
101 Transportation Building
104 South Mathews Avenue
Urbana, IL 61801

Dr. C. P. Li
NASA Johnson Space Center
Mail Code ED311
Houston, TX 77058-3696

Dr. Jim Luckring
NASA Langley Research Center
MS 280
Hampton, VA 23665-5225

Dr. Raymond Luh
NASA Ames Research Center
MS T045-2
Moffett Field, CA 94035

Mr. Mike Madson
NASA Ames Research Center
MS 227-2
Moffett Field, CA 94035

Dr. Paul K. McConnaughy
NASA Marshall Space Flight Center
MS ED32
Marshall Space Flight Center
AL 35812-5001

Mr. Mark McMillin
NASA Langley Research Center
MS 365
Hampton, VA 23665-5225

Mr. John Melton
NASA Ames Research Center
MS 227-2
Moffett Field, CA 94035

Dr. Marshal Merriam
NASA Ames Research Center
MS 202A-14
Moffett Field, CA 94035

Mr. David P. Miller
NASA Lewis Research Center
MS 77-6
21000 Brookpark Road
Cleveland, OH 44135-3191

Mr. Young-June Moon
NASA Lewis Research Center
MS SVR-1
21000 Brookpark Road
Cleveland, OH 44135-3191

Dr. Charles Nietubicz
Ballistics Research Laboratory
Aberdeen Proving Ground
Maryland, 21005-5066

Ms. Pam Richardson
Code RF, Headquarters
Washington DC 20546

Dr. Yehia Rizk
NASA Ames Research Center
MS 258-1
Moffett Field, CA 94035

Dr. Mani Salas
NASA Langley Research Center
MS 258-1
Hampton, VA 23665-5225

Dr. Mark Sheppard
Rensselaer Design Research Center
Rensselaer Polytechnic Institute
Troy, NY 12180-3590

Mr. Jaiwon Shin
NASA Lewis Research Center
MS 77-10
21000 Brookpark Road
Cleveland, OH 44135-3191

Mr. Merritt Smith
NASA Ames Research Center
MS T045-2
Moffett Field, CA 94035

Dr. Robert Smith
NASA Langley Research Center
MS 125
Hampton, VA 23665-5225

Mr. Aaron Synder
NASA Lewis Research Center
MS 5-11
21000 Brookpark Road
Cleveland, OH 44135-3191

Mr. Reese Sorenson
NASA Ames Research Center
MS T045-2
Moffett Field, CA 94035

Mr. Don J. Sosoka
NASA Lewis Research Center
MS 142-2
21000 Brookpark Road
Cleveland, OH 44135-3191

Mr. Jerry South
NASA Langley Research Center
MS 128
Hampton, VA 23665-5225

Dr. Sharon Stanaway
NASA Ames Research Center
MS 258-1
Moffett Field, CA 94035

Dr. Joseph L. Steger
Department of Mechanical Engineering
University of California
Davis, CA 9561

Mr. John Steinbrenner
General Dynamics Corporation
Mail Zone 267
P. O. 748
Fort Worth, TX 7610

Dr. Bernard Su
Boeing Commercial Airplane Co.
MS 7K-02
P. O. Box 3707
Seattle, WA 98124

Mr. Scott Thomas
NASA Ames Research Center
MS 258-1
Moffett Field, CA 94035

Dr. Joe F. Thompson, Director
Research Center for Advanced Scientific Computing
Mississippi State University
Mississippi State, MS 39762

Dr. William Van Dalsem
NASA Ames Research Center
MS T045-2
Moffett Field, CA 94035

Dr. Alison A. Vogel
NASA Ames Research Center
MS T045-2
Moffett Field, CA 94035

Dr. Giuseppe Volpe
Staff Scientist
Grumman Corporation Research Center
MS A08-35
Bethpage, NY 11714

Mr. Ed Waggoner
NASA Langley Research Center
MS 294
Hampton, VA 23665-5225

Dr. Velvin Watson
NASA Ames Research Center
MS 258-2
Moffett Field, CA 94035

Mr. Jim Weilmuenster
NASA Langley Research Center
MS 366
Hampton, VA 23665-5225

Dr. Bob Weston
NASA Langley Research Center
MS 128
Hampton, VA 23665-5225

Mr. Jeff White
NASA Langley Research Center
MS 156
Hampton, VA 23665-5225

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W. R. Van Dalsem, R. E. Smith (NASA Langley, Hampton, VA 23665), Y. K. Choo (NASA Lewis, Cleveland, OH 44135), L. D. Birckelbaw, and A. A. Vogel

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Ames Research Center
Moffett Field, CA 94035-1000

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Point of Contact: W. R. Van Dalsem, Ames Research Center, MS T045-2, Moffett Field, CA 94035-1000
(415) 604-4469 or FTS 464-4469

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13. ABSTRACT *(Maximum 200 words)*

This publication is a summary of the paper sessions and panel discussions of the NASA Workshop on Future Directions in Surface Modeling and Grid Generation held a NASA Ames Research Center, Moffett Field, California, December 5-7, 1989. The conference was initiated by the Office of Aeronautics and Exploration Technology (OAET). The purpose was to assess U.S. capabilities in surface modeling and grid generation and take steps to improve the focus and pace of these disciplines within NASA. The organization of the workshop centered around overviews from NASA centers and expert presentations from U.S. corporations and universities. Small discussion groups were held and summarized by group leaders. Brief overviews and a panel discussion by representatives from the DoD were held, and a NASA only session concluded the meeting. In the NASA Program Planning Session summary there are five recommended steps for NASA to take to improve the development and application of surface modeling and grid generation.

14. SUBJECT TERMS

Surface modeling, Grid generation, Computational fluid dynamics

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